1.2.8 DAQ

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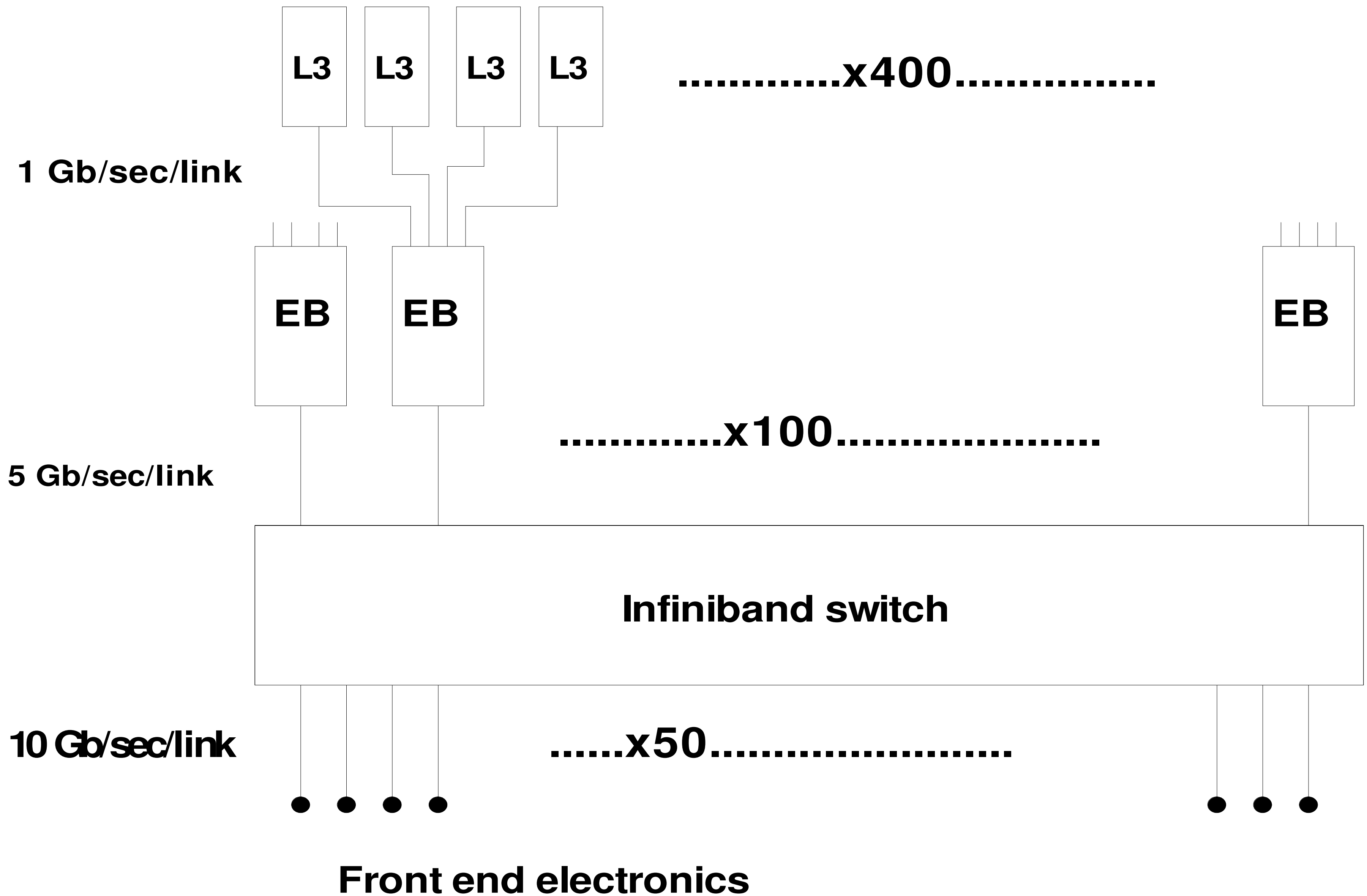
Scope of subsystem

- The DAQ system transfers digitized data from the detector to permanent storage. DAQ consists of three main components
  - Event Builder
  - Level 3 Trigger
  - Online Software
- Event Builder receives digitized data from the front-end electronics, and combines the event fragments into complete events. Based on a farm of computers communicating with the front-end electronics through a network switch.
- Level 3 Trigger receives complete events from the Event Builder and applies additional filtering criteria before sending the events to permanent storage. Level 3 Trigger can also perform detector calibrations/monitoring on the fly.
- Online software holds everything together. It includes a run controller, a user interface, an event logger, interfaces to the Event Builder, to the L1/L3 trigger systems, to the slow control and to the monitoring/calibration tasks.

Data Flow


L3
L3
L3
L3
.............x400...............
1 Gb/sec/link
EB
EB
EB
.............x100....................
5 Gb/sec/link
Infiniband switch
10 Gb/sec/link
......x50.......................
Front end electronics

Performance goals

- Input rate (L1 accept rate): ~ 1 Mhz
- Output rate (to storage): few kHz
- Data transfer rate: 30 GByte/sec into Event Builder
- Small trigger acceptance loss (use of offline algorithms)
- Flexibility to implement new triggers, adapt to new conditions
- Rapid startup, low down-time and natural upgradeability due to the use of “battle tested” software base borrowed from CMS, and mostly commercial computing and networking hardware

R&D status and plans

- Small test cluster obtained for EB/L3 tests
  - 4 PCs with dual 3.2 GHz Xeon, PCI-E, IB 4X interface
  - 2 PCs with dual 1.5 Ghz Itanium2, 64bit PCI-X, IB 4X interface
  - 8 port IB switch
  - Simple data transfer tests: 700 MB/sec per link
- Event Builder near term plans:
  - More detailed estimate of data rates
  - Measurement of real-time performance of IB-based Evt Builder
- L3 trigger:
  - Development of trigger algorithms and a coherent picture of DAQ and trigger at all levels
  - Measurement of real-time performance of an “all software” L3
  - Preliminary design and feasibility studies for custom L3 hardware
- Online software:
  - Implementation/customization of XDAQ software

RSVP Review Status Sheet
Due in RSVP Project Office on January 14, 2005

WBS No. 1.2.8 Title: "DAQ" **Date 01/03/05**

Preparer/Manager: "George Redlinger" **Current Cost Est. (FY05 $M)= 5.72**
Assigned Contingency % = 25.4%

Cost Elements (FY05$M): Matls. = 2.53; Effort = 2.03; Ohd. = ee.f; Conting. = 1.16; Total = 5.72

WBS Dictionary Definition:
DAQ refers to the transfer of digitized data from the front-end electronics after a Level 1 trigger accept. DAQ consists of three main components: Event Builder, Level 3 Trigger and Online Software. The Event Builder receives digitized data from the front-end electronics and combines the event fragments into complete events. The Event Builder is based on a farm of computers communicating with the front-end electronics through a network switch. The Level 3 trigger receives complete events from the Event Builder, applies additional event filtering criteria and sends the surviving events to permanent storage; it can also perform detector calibrations and monitoring in real-time with access to a much larger data set than would be available from permanent storage. The Level 3 trigger is based on a farm of computers communicating with the Event Builder computers through Gigabit ethernet. Online Software is the glue that holds the DAQ system together. It includes a run controller, a user interface, an event logger, interfaces to the Event Builder, to the L1/L3 trigger systems, to the slow control and to online monitoring/calibration tasks.

Technical Level of Confidence:	*Prototype* Demonstrated	__	*Elements* Built & Tested	__
(choose one)	Similar *system* exists	__	Similar *technology* works	X
	Novel system concept	__	No candidate concept yet	__
	Other (Comment)			

Basis of the Cost Estimate:	Commercial product	44%	Engineered design	0%
(by percentage of total cost;	Engineered conceptual	0%	Scientist conceptual	56%
sum of fractions a-f = 100%)	Guess	0%	Other (specify)	0%

Status of Hardware/Software Development:
The hardware for the Event Builder and part of the Level 3 Trigger is based on commercial computing and networking hardware. There is a possibility for a custom hardware component to the Level 3 Trigger; only a scientist's concept exists for this. The software to control the Event Builder, Level 3 Trigger and the overall data flow will be based heavily on the CMS XDAQ project. Apart from examining the suitability of XDAQ software for KOPIO, no work has been done on customizing it for the experiment. Software for the Level 3 trigger algorithms will need to be written; only a vague idea of the effective algorithms exists at the moment.

Issues (funding, collaborator shortage, engineering help, etc.):

Event Builder:
1. More detailed estimate of data rates from simulation
2. Measurement of real-time performance of small-scale prototype

Level 3 trigger:
1. Development of trigger algorithms and a coherent picture of DAQ and trigger across all levels
2. Measurements of real-time performance on a small-scale prototype. Requires substantial development in the area of offline analysis.
3. Need for custom hardware for Level 3 depends on the as yet unknown performance of the software trigger. No design, no engineer working on this (yet); some prospects of collaboration with BNL Instrumentation.

Manpower:
We need more manpower. Currently we have only one physicist and one electronics technician. Ultimately we need a core of at least 3 physicists and one software engineer to implement the Event Builder, Level 3 Trigger and Online Software. For the Level 3 Trigger algorithm development, we rely heavily on the existence of manpower to develop the offline analysis tools (costed under Offline Software). For the custom Level 3 hardware, we need in addition one electronics engineer and one physicist.

Backup material

DAQ Cost Summary (k$)

Item	Description	Materials	Labor	Base Cost	Contingency (%)
1.2.8	DAQ	2530	2032	4562	29
1.2.8.1	Event Builder	830	0	830	32
1.2.8.2	Level 3 trigger	1200	0	1200	34
1.2.8.3	Hardware co-proc	500	1171	1671	28
1.2.8.4	Online software	0	635	635	10
1.2.8.5	Administration	0	226	226	6

- Costs updated following comments from 11/09/04
- Contingency re-estimated

1.2.8.1 Event Builder

Item	Description	Materials	Labor	Base Cost	Contingency (%)
1.2.8.1	Event Builder	830	0	830	32

- Receives event fragments from the front-end electronics and builds complete events. Based on a cluster of PC's communicating through a network switch
- Cost drivers are Infiniband network switch (150 ports, 10 Gbit/sec per port), and event builder computers (160 CPU's)
- Data rate from Geant with assumptions. Needed processing power estimated by scaling up from E949. Computer costs from Dell website. Network switch cost from chatting with vendors at trade shows.
- Labor by physicists
- Issues
  - More careful estimates of event size
  - Measurements of real-time performance
- Risk factors
  - Design and cost risks from lack of information on event size, L1output rate, real-time performance of hardware

1.2.8.2 Level 3 Trigger

Item	Description	Materials	Labor	Base Cost	Contingency (%)
1.2.8.2	Level 3 trigger	1200	0	1200	34

- Receives complete events from Event Builder, applies software trigger, sends survivors to mass storage. May also perform detector calibrations in real-time. Based on a cluster of PC's communicating with the Event Builder computers.
- Cost driver is computer farm (400 CPUs). Cost estimated from vendor web pages.
- Assumed processing time of 200μs/event per CPU.
- Labor is by physicists
- Issues:
  - Development of trigger algorithms, coherent picture of trigger/DAQ across all levels
  - Measurements of real-time performance
- Risk factors
  - Design and cost risks from lack of information on L3 input rate, real-time performance of hardware

1.2.8.3 Hardware co-processor

Description	Materials	Labor	Base Cost	Contingency (%)
Hardware co-processor	500	1171	1671	28

- Custom hardware to perform CPU-intensive trigger calculations
- Cost drivers are FPGA costs and engineering/technician labor. FPGA costs from arrow.com
- Issues:
  - Need for this system depends on performance of software trigger
  - No design, no engineer working on this (yet); some prospects of collaboration with BNL Instrumentation. Number of FPGA's needed estimated by pure speculation.
- Risk factors:
  - Design and cost risks from lack of information on L3 input rate, real-time performance of L3 software
  - Lower contingency than EB and L3 because some of the costs are labor costs that are thought to be better known. Also lower schedule risk since fully working system likely not needed at start of beam.

1.2.8.4 Online Software

Item	Description	Materials	Labor	Base Cost	Contingency (%)
1.2.8.4	Online software	0	635	635	10

- Online software is the glue that holds the DAQ system together. It includes a run controller, a user interface, event logger, interfaces to the event builder, to the L1/L3 trigger systems, to the slow control and to online monitoring/calibration tasks.
- Based on free software plus our own code. Labor is mostly by physicists. One software engineer is added.
- Issues:
  - None. Just needs to get done
- Risk factors:
  - Some schedule risk

1.2.8.5 Administration

Item	Description	Materials	Labor	Base Cost	Contingency (%)
1.2.8.5	Administration	0	226	226	6

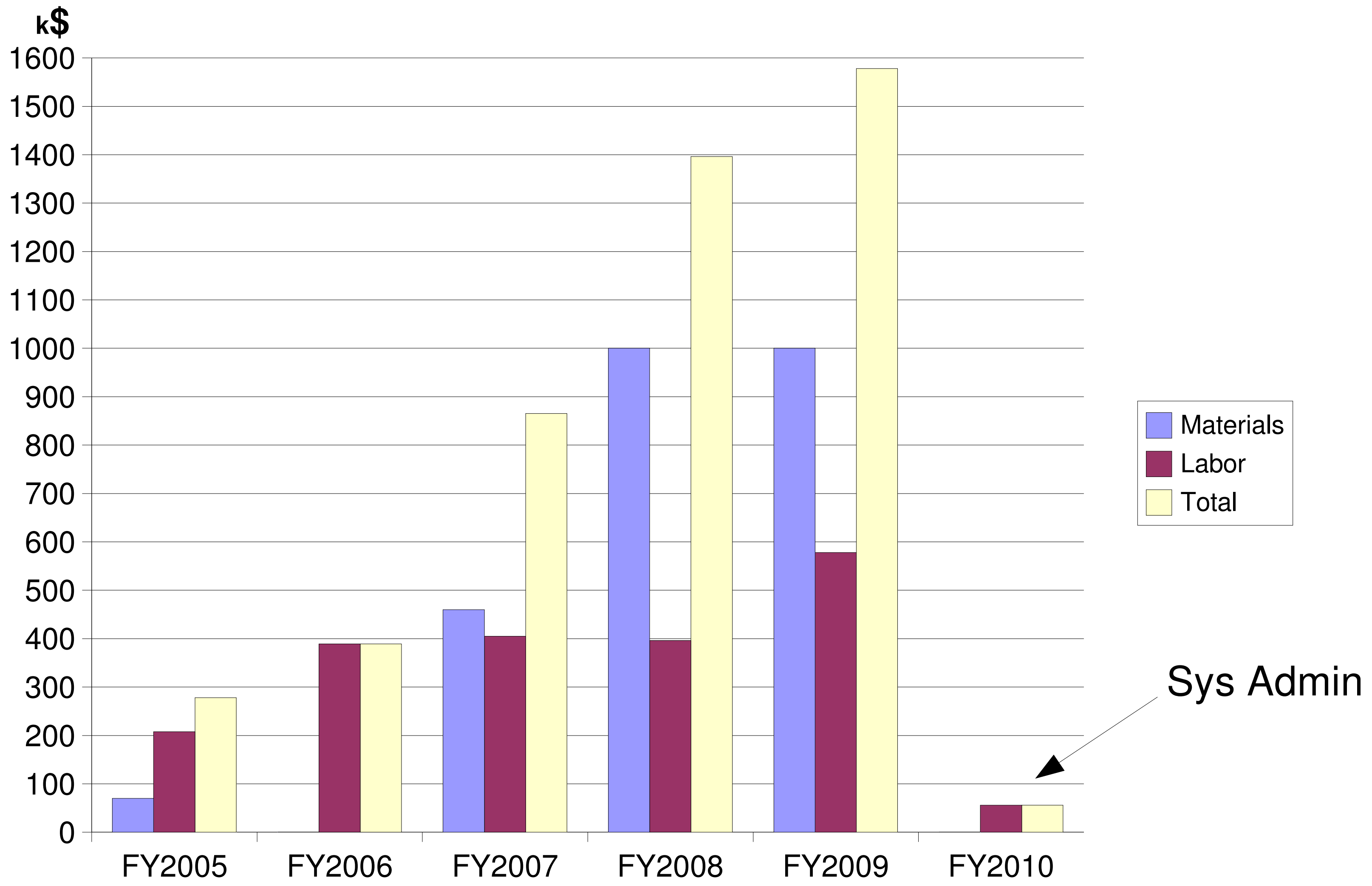
- System Administrator to look after networking and PC farms.
- Issues: none
- Risk factors: none, except that if we do not have an administrator, a physicist will take on the tasks, resulting in some schedule risk

Schedule

Event builder, L3 trigger and online software.

- I assume a core of 3 physicists (with hopefully some help from postdocs and perhaps students, neither of whom I have costed).
- R&D phase of roughly 1.5 years for EB and L3.
  - Event builder throughput
  - L3 trigger algorithm development, speed measurements
- I'm assuming we will have a beam test at some point of the PR+CAL system. Would like to test “prototype” DAQ system in that environment. Earliest time we could have this ready is Fall 2006.
- First major purchsse (25% of final system) around mid-2007.
- Refinement of design, test with the 25% system (1 year, 3 physicists + 1 software engineer)
- Purchase of remaining hardware around mid-2008.
- Installation/integration: 1 year, 3 physicists + 1 software engineer
- Complete by July 2009

Spending profile



DAQ/L3 complete 7/1/09 in current schedule

Cost Growth

- TDR cost $1585k —> new base cost $4562k
- Not terribly meaningful to compare due to major change in architecture and in scope
  e.g. L1 accept rate: 25 kHZ —> several hundred kHz
- Bulk of TDR cost was from buffer modules and readout controllers ($1513k). These no longer exist; their function was moved down to the front-end electronics.
- On the other hand, we added or expanded as follows:

Item	TDR cost (k$)	Current cost (k$)
Test cluster	0	70
Event builder switch	12	180
Event builder farm	40	520
L3 trigger farm	20	920
Disks, peripherals	0	200
System Admin	0	226
Software engineer	0	635
Hardware coprocessor	0	1700

Contingency analysis

In the following table, the dominant risk factors for each WBS item are shown. The column marked contingency is calculated by properly weighting over all the elements of that WBS item.

Item	Technical	Cost	Schedule	Design	Wt. factor	Contingency(%)
Event Builder	1	10	8	15	1	32
L3 trigger	1	10	8	15	1	34
Hardware coprocessor	1	15	4	15	1	28
Online software	1	1	8	0	1	10
Administration	1	1	4	0	1	6

Comments:

- Technical risk set to 1 for all items since we will use off-the-shelf components
- Weighting factors set to 1. Uncertainties are in material cost and in design.
- Costs for EB and L3 estimated by scaling from E949 requirements. Cost for co-processor comes from engineering judgment; overall contingency is lower than EB and L3 because co-processor has significant contribution from engineering/technical labor cost, which has lower uncertainty

Manpower

- Currently only G. Redlinger (physicist) and H. Diaz (electronics technician)
- Ultimately we will need a core of 3 physicists and one software engineer for EB/L3 and online software. For the co-processor project, we need in addition one electronics engineer, one electronics technician and one physicist.
- We need more manpower!